

# Engineering the Ideal Array



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**Microsystem Technology Symposium**  
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# RF Arrays in Military Systems



THAAD



XBR



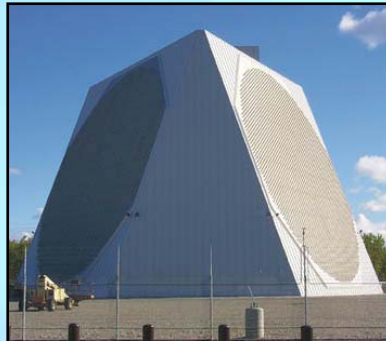
AN/MPQ Sentinel



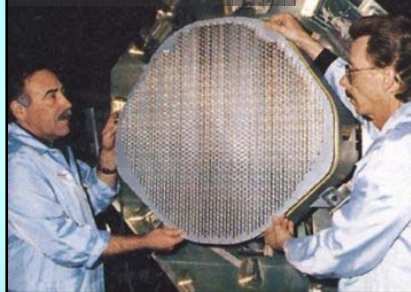
JLENS



AN/SPY-1D  
(USS Mason)



AN/APG-77 (F-22)



AN/SPY-1D



AN/APG-73  
(F/A-18)



AN/SPY-1



AN/TPQ-37



AN/APG-81 (JSF)



JSTARS



MILCOM



***Arrays are the heart of sensor systems for many military platforms***

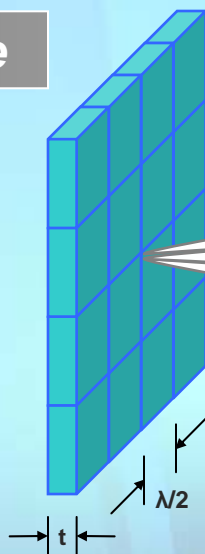


# Ideal Array: The Vision



## Architecture

- Scalable
- Reconfigurable
- Embedded thermal management
- Negligible mass
- Wafer-thin
- Dirt cheap



## Transmit

- Huge transmit power available
- Enormous bandwidth
- Near-unity power added efficiency

## Beamsteering

- Precise phase & amplitude control of each element
- Near-instantaneous speed
- Suppressed sidebands

## Receive

- Near-zero noise figure
- Enormous dynamic range
- Minimal power dissipation

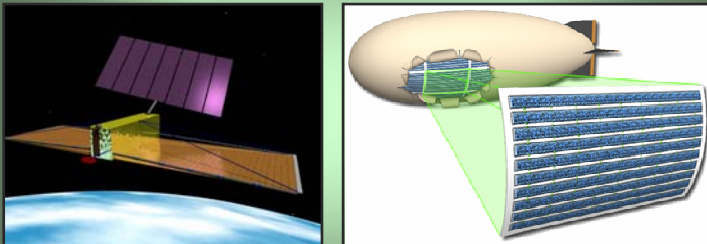
*All we need now is a bit of technology...*



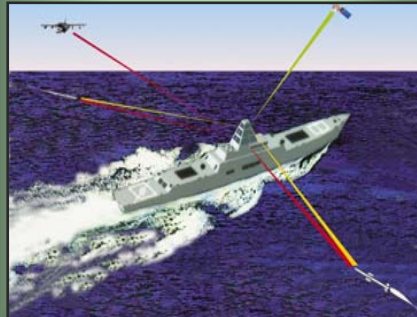
# What Does it Enable?



## Massive Sensor Arrays



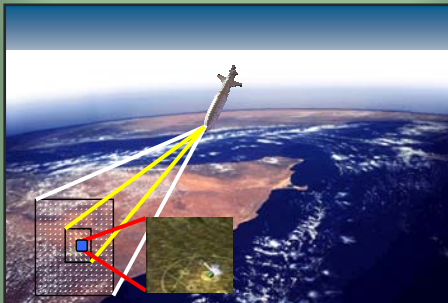
## Multi-function Systems



## Conformal Sensors



## Frequency Agile Sensors



## Greater Range



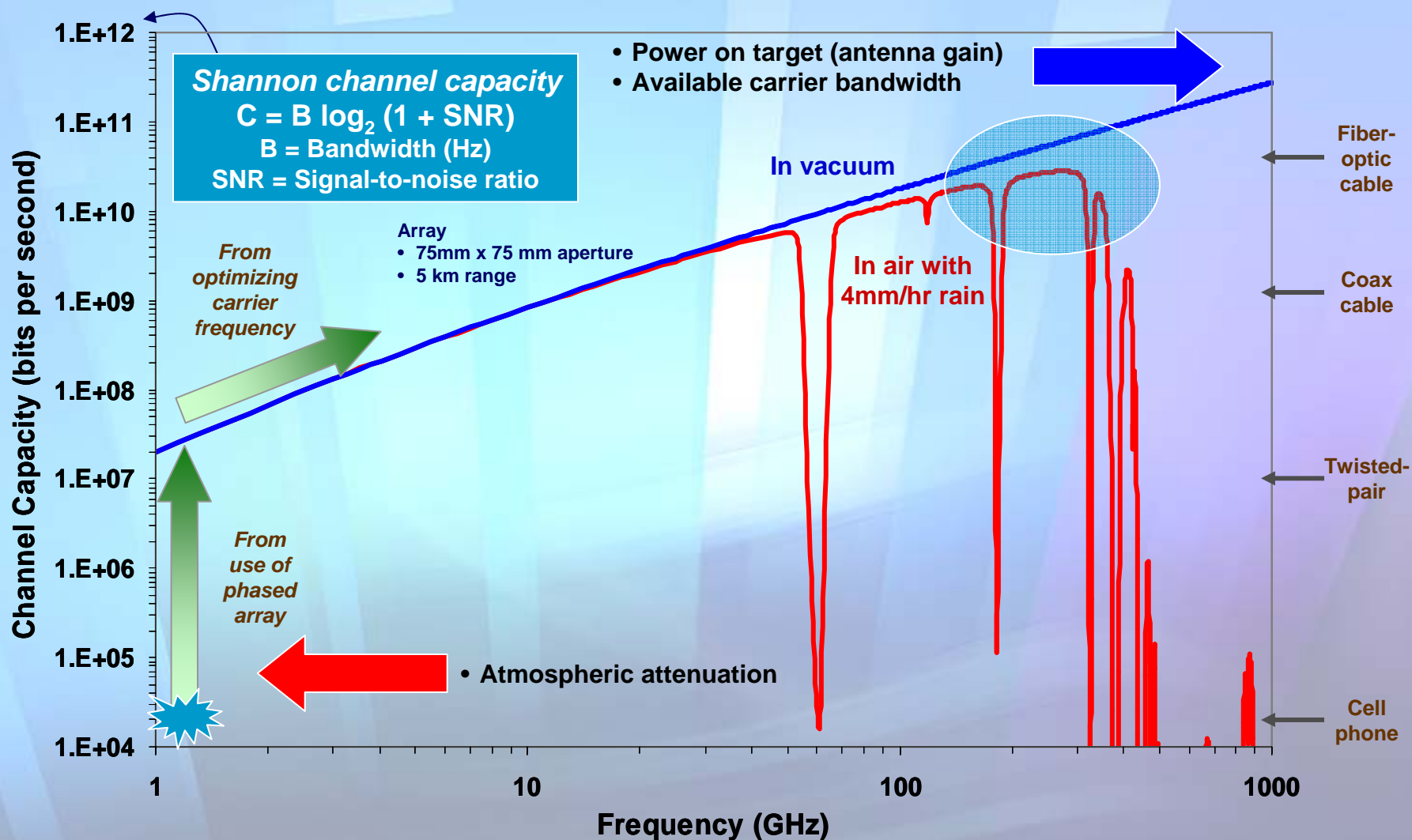
## Reduced System Size



***Compact, robust, intelligent sensor and communications systems***



# The Ideal Array and Frequency



*For many applications, the ideal array is a millimeter-wave array*



# Arrays in Military Systems



THAAD



XBR



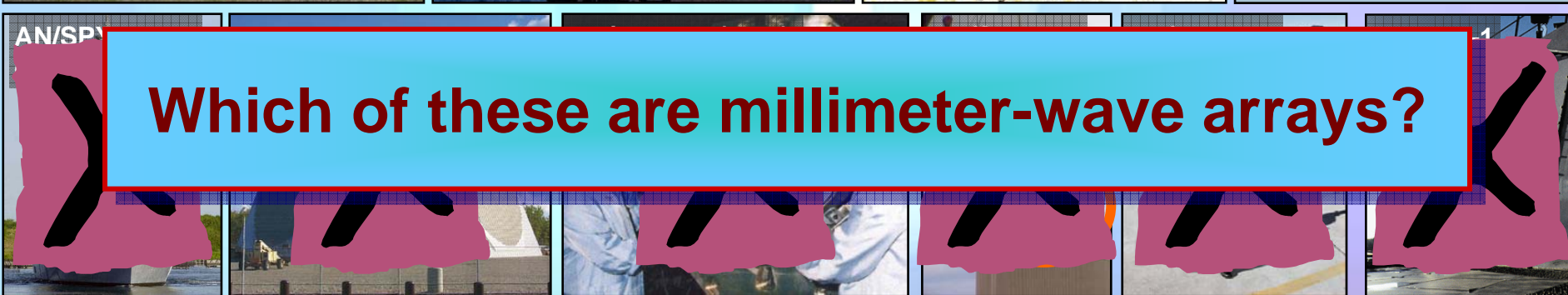
AN/MPO Sentinel



JLENS



AN/SPN



Which of these are millimeter-wave arrays?

AN/TPO-37



AN/APG-81 (JSE)



JSTARS



MILCOM



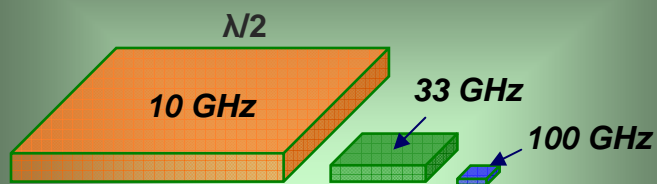
*Arrays are the heart of sensor systems for many military platforms*



# The High Frequency Array

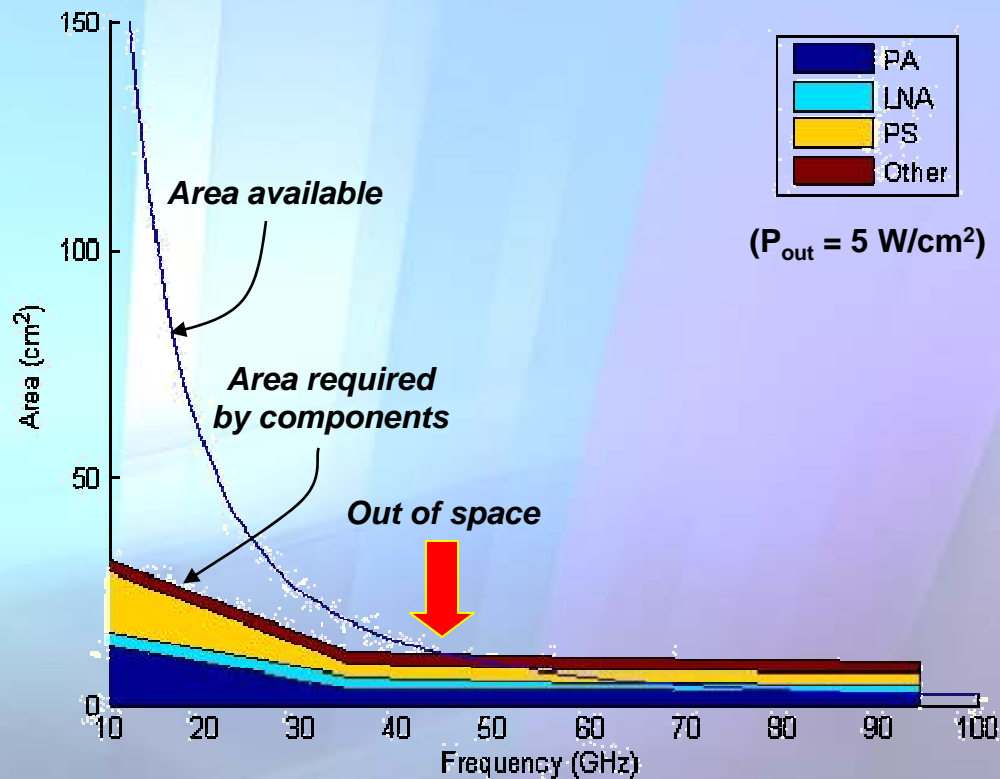


Area of an array cell scales like  $f^2$



Each cell must still contain...

- LNA
- Power amp
- Filtering
- Diplexer/ circulator
- Phase shifting
- Limiter
- Digital control
- ...



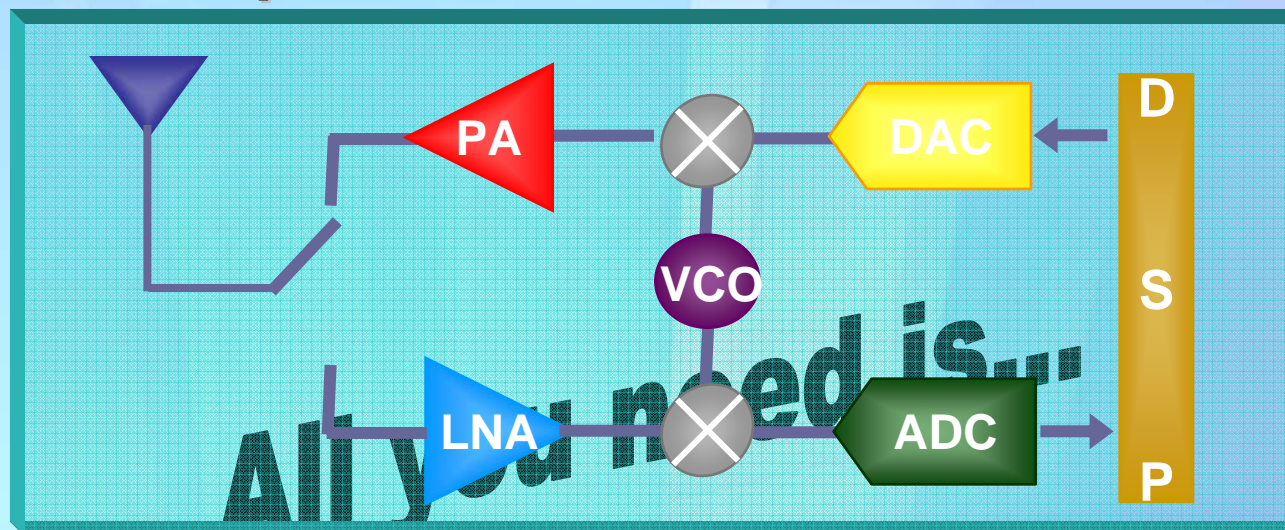
**3D is only way to cram functionality into increasingly smaller pitch**



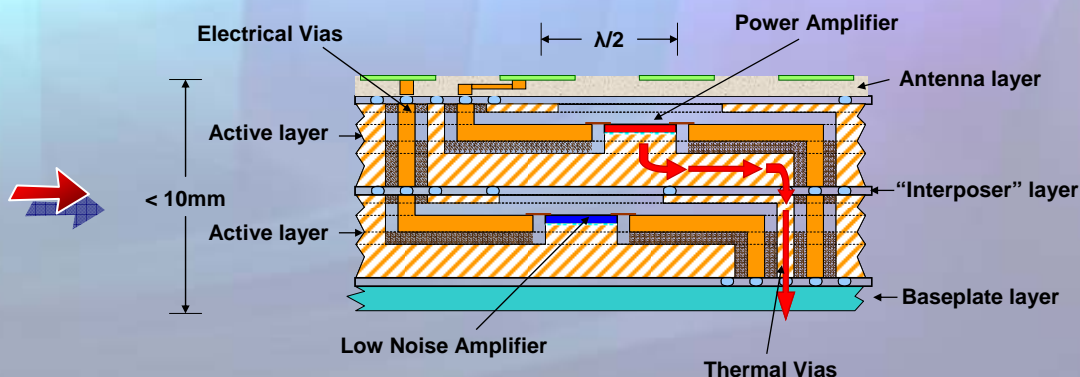
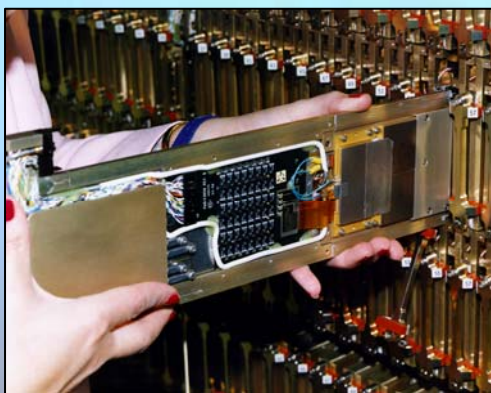
# Challenges for an Ideal Array



## Ideal circuit components



## Ideal integration methods

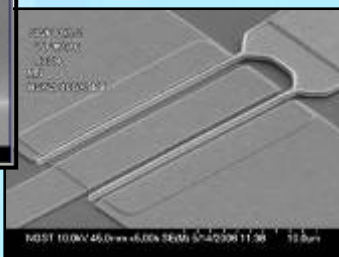




# The High Frequency Integrated Circuit

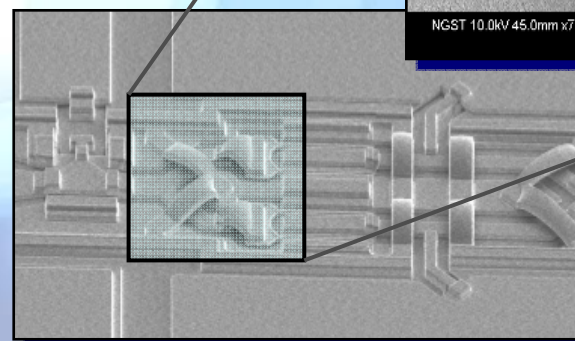
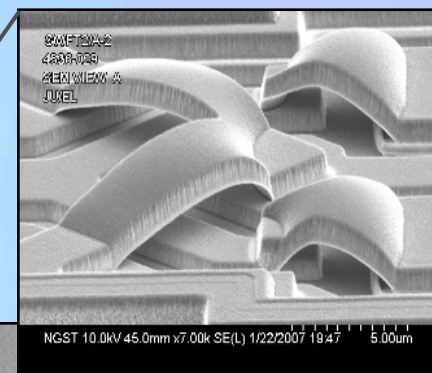
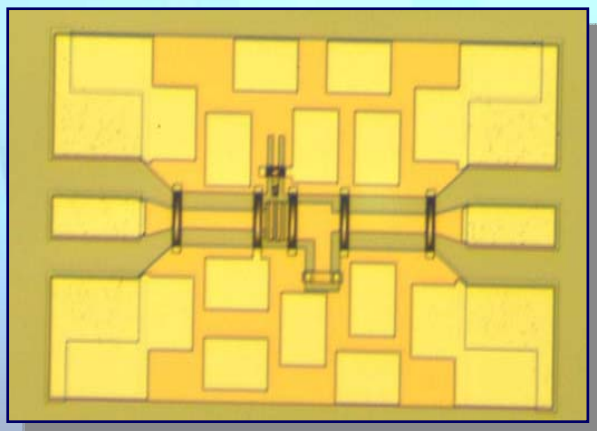


**35nm gate InP HEMT transistor  
with record  $G_m = 2300\text{mS/mm}$**



**S-MMIC process  
development**

**347 GHz Integrated Circuit:  
World's First "s-MMIC"**

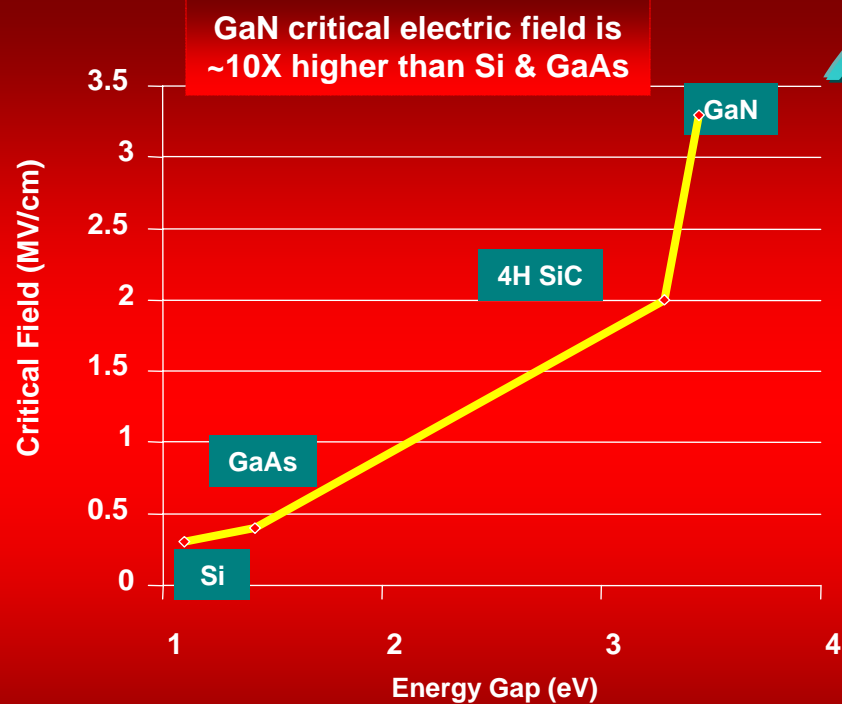


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Space Technology

**THz frequency integrated circuits are becoming a reality**



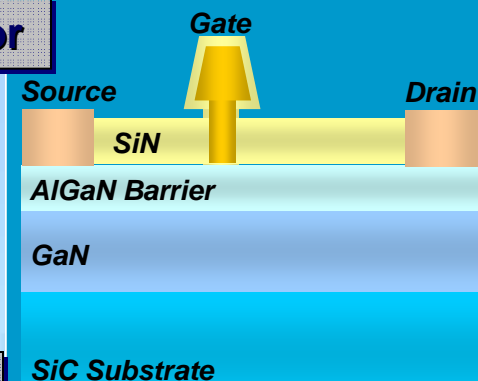
# Wide Bandgap Semiconductors



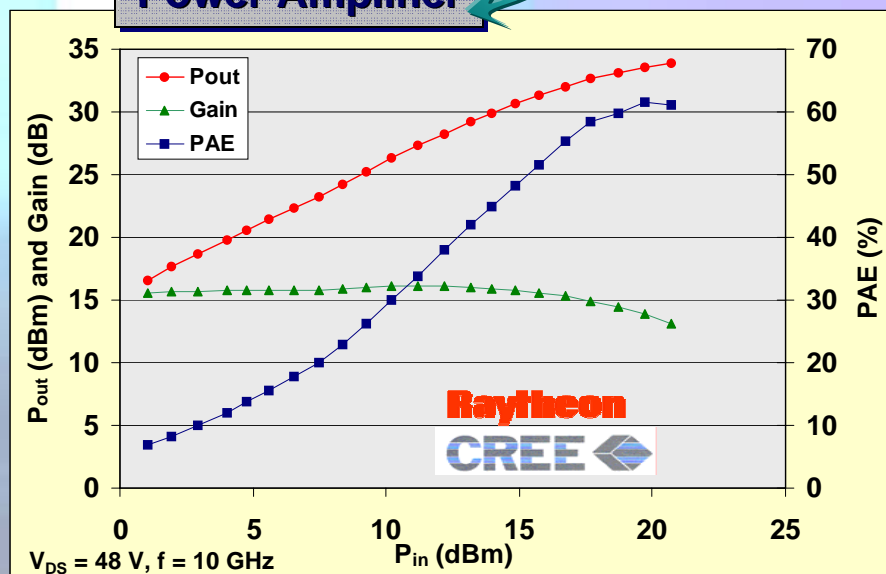
## GaN HEMT Transistor

Dramatically higher:

- Output power
- Efficiency
- Bandwidth



## GaN HEMT Power Amplifier



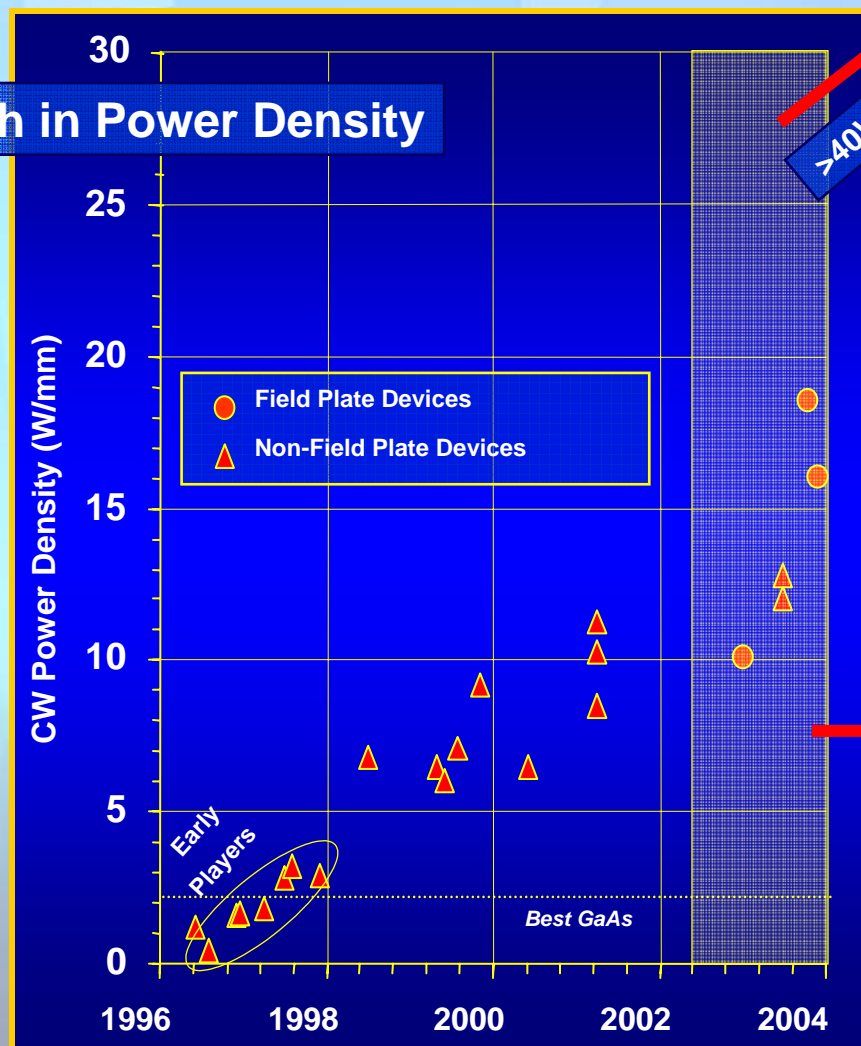
*The ideal array demands the ideal power amplifier transistor material!*



# GaN & Power Density



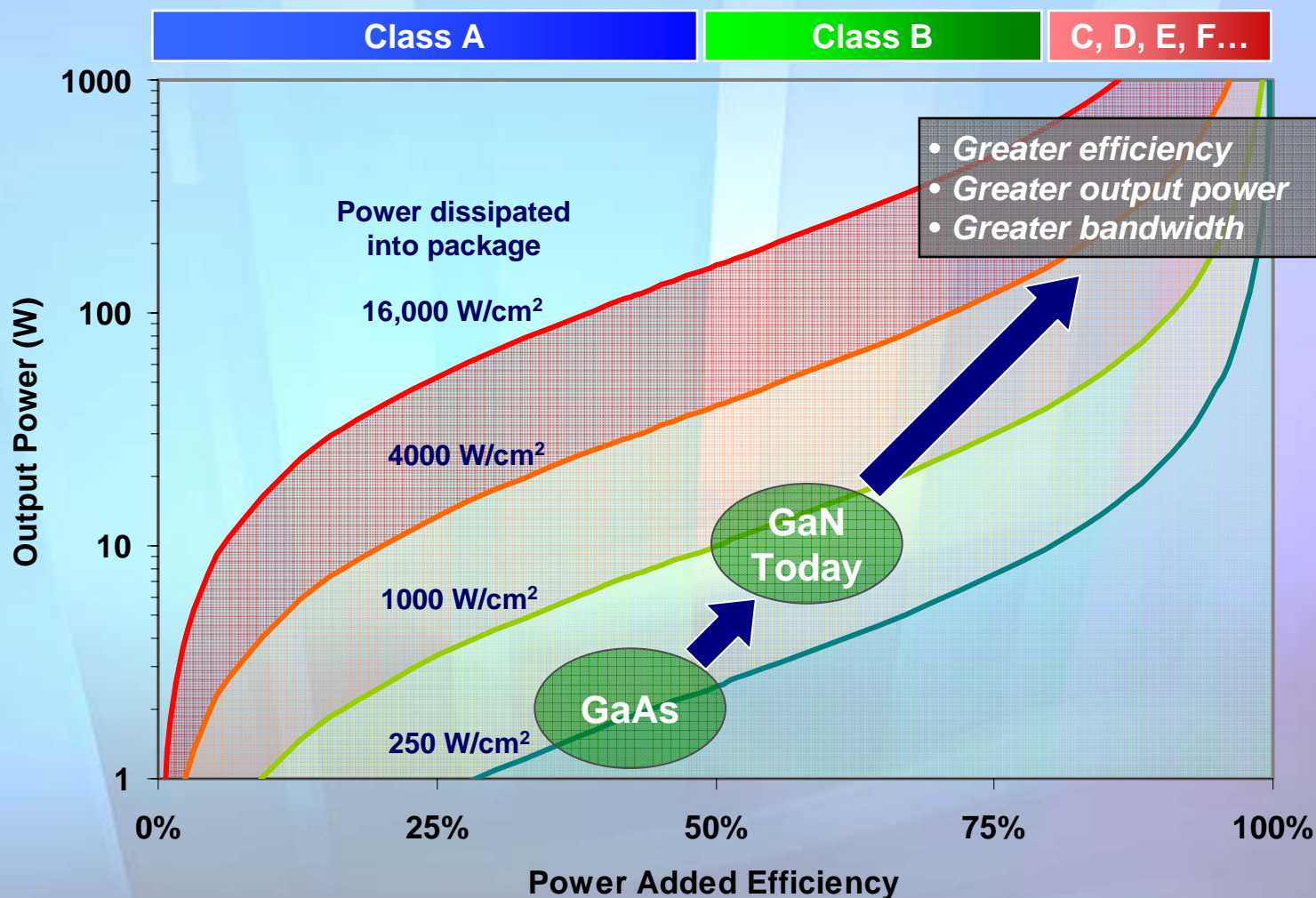
**A Breakthrough in Power Density**



***For large GaN devices, we are still a long way from the material limit***



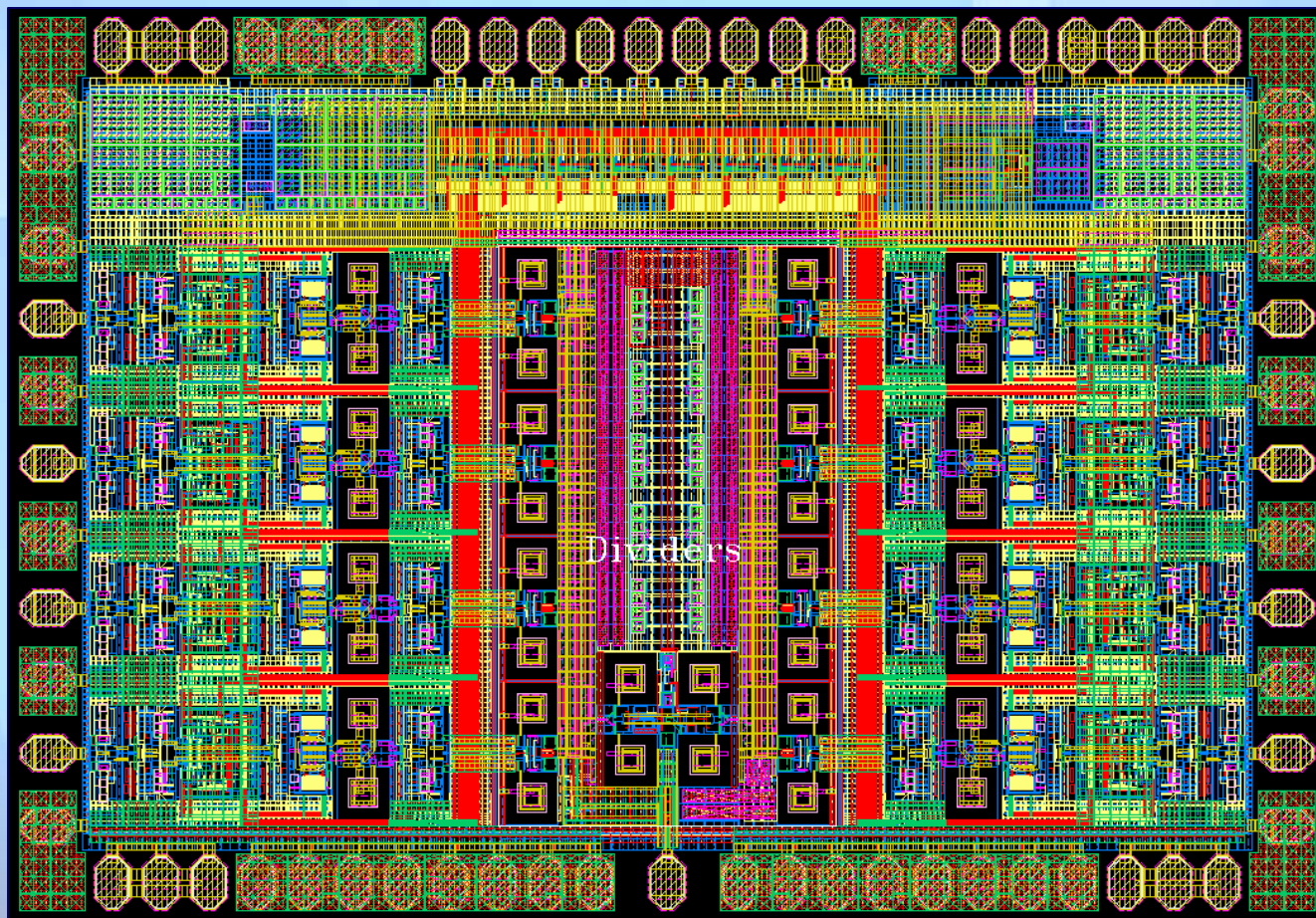
# The Ideal Power Amplifier



*The ideal PA demands a new focus on thermal management*



# Complete Beamformer-on-a-Chip



- 44GHz
- 8 channels
- All beamforming functions
  - RF amplifiers
  - 4-bit phase shifters
  - Amplitude controllers
  - Summing network
  - Power control
  - Latches for phase state
  - Address decoders
  - Digital-to-analog converters

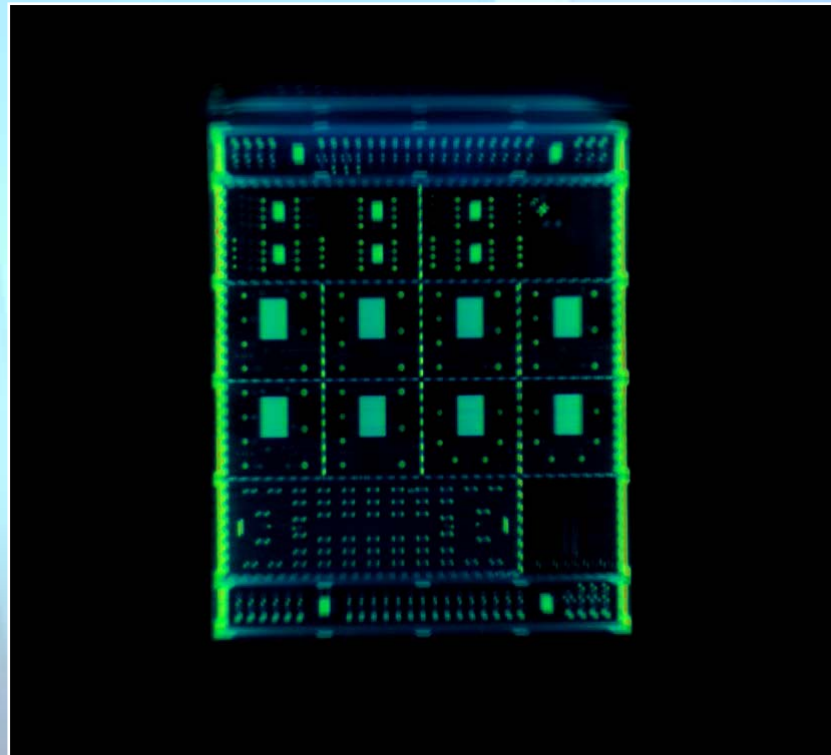
→ 2.2x2.4 mm ←

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 **UCSD**



# 3D Integration of an RF Array

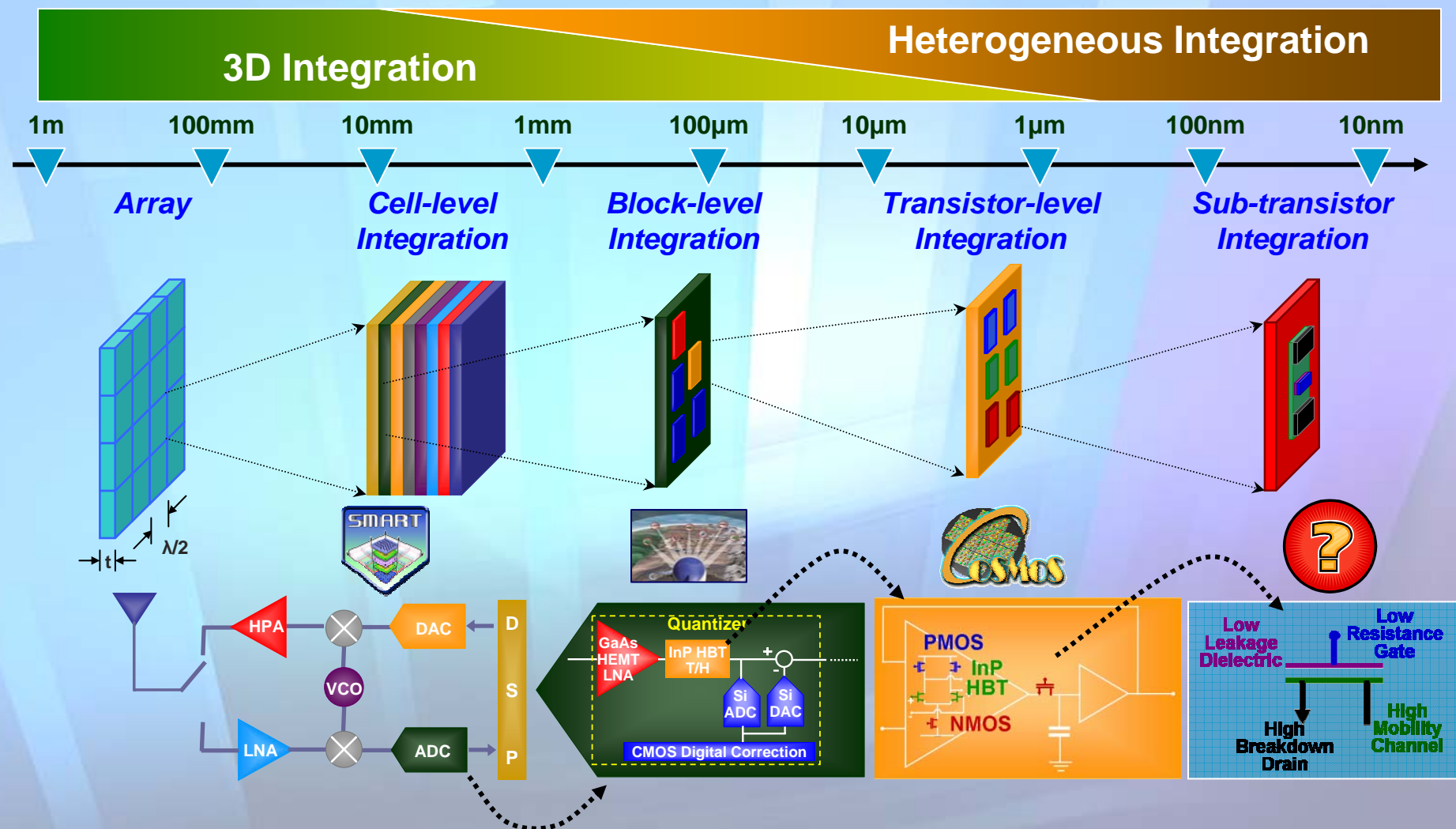


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*Space Technology*

***Today: integrated circuits; Tomorrow: integrated arrays***



# Constructing the Ideal Array



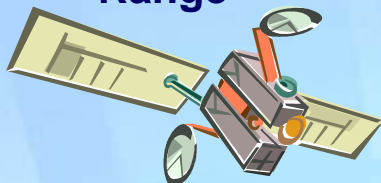
*Integration occurring on all length scales*



# The Challenge



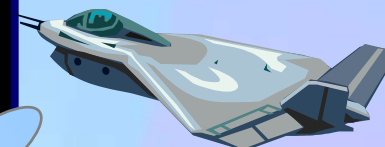
Range



Integrated

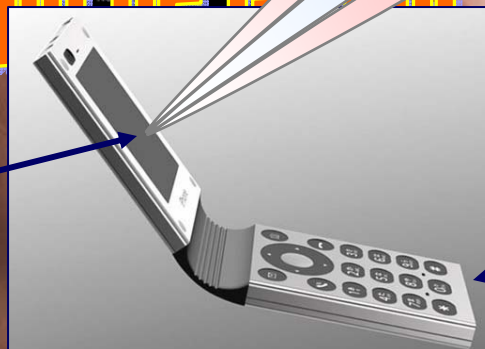
Massive capacity  
( $>$  coax cable)

Highly directional;  
low probability of  
intercept



What could be even better than this?

Array no larger  
than display



Highly  
efficient

**Your 200GHz MTO-Phone...**

*...made possible by DARPA & the ideal array*